CE257 Data Communication and Networking

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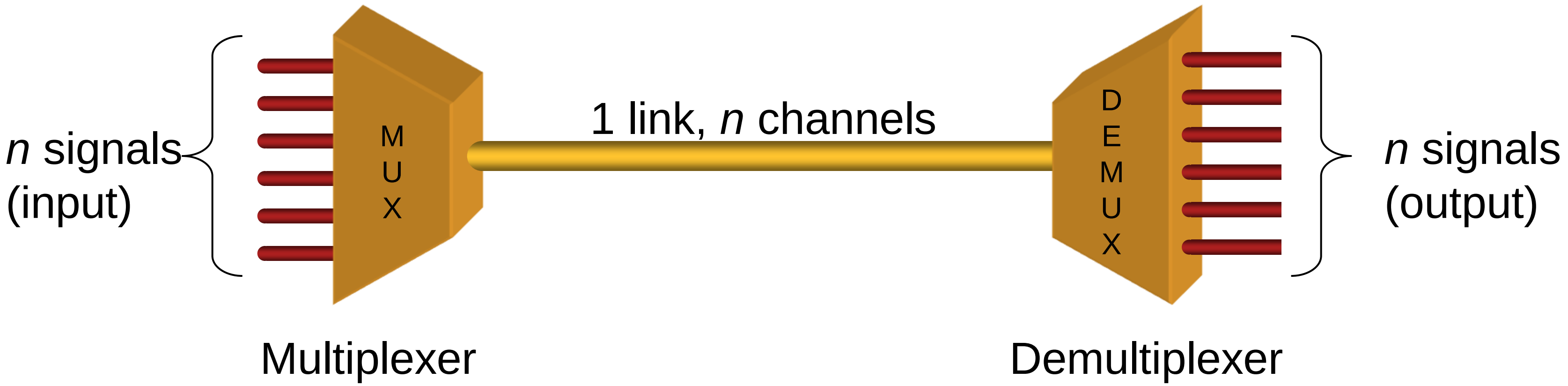
CE257 Data Communication and Networking

Week 6 – Session 1

STUDENTS WILL LEARN

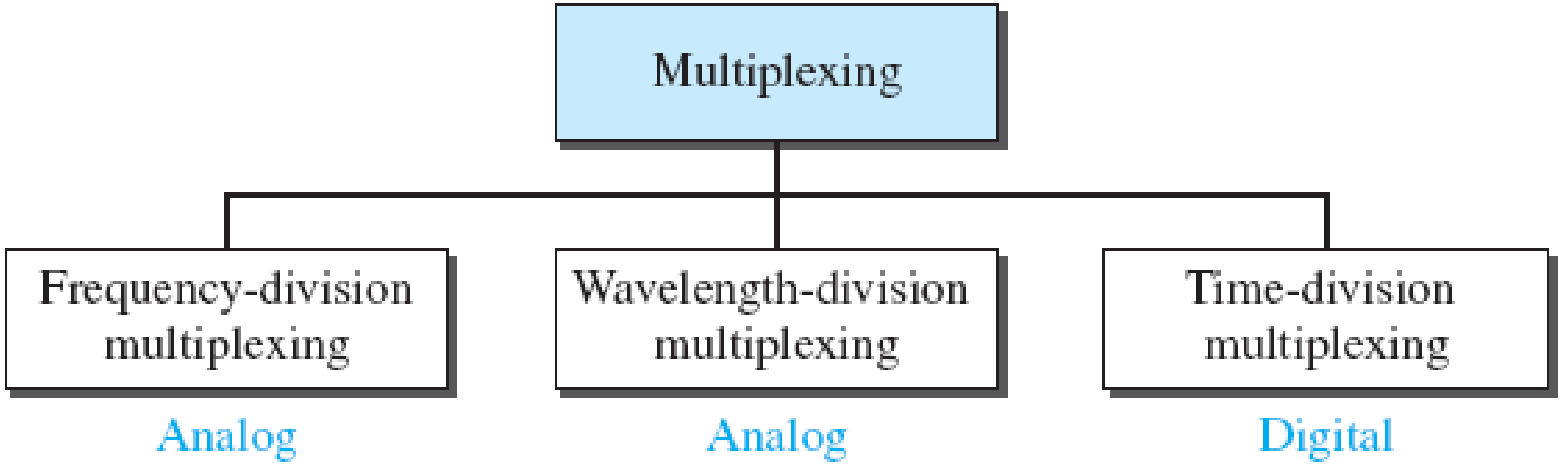
- Multiplexing and Spreading
  - multiplexing and spectrum spreading.
  - In multiplexing, our goal is efficiency; we combine several channels into one.
  - In spectrum spreading, our goals are privacy and antijamming; we expand the bandwidth of a channel to insert redundancy, which is necessary to achieve these goals.

DIVING LINK INTO CHANNEL



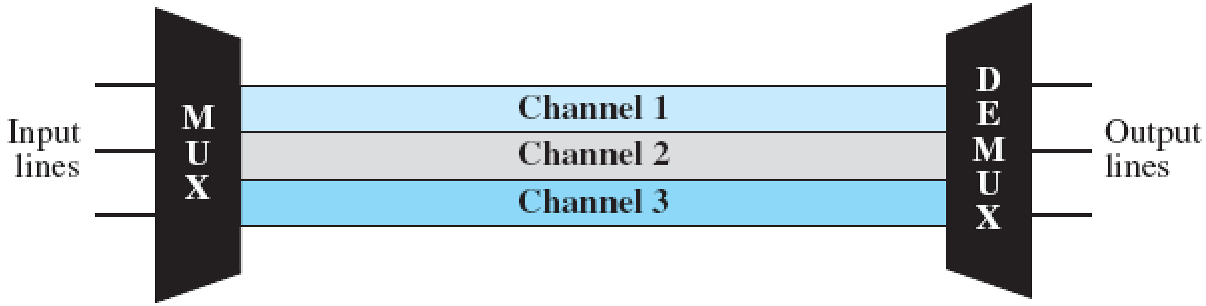
- Link =Wire
- Channel=f

MULTIPEXING

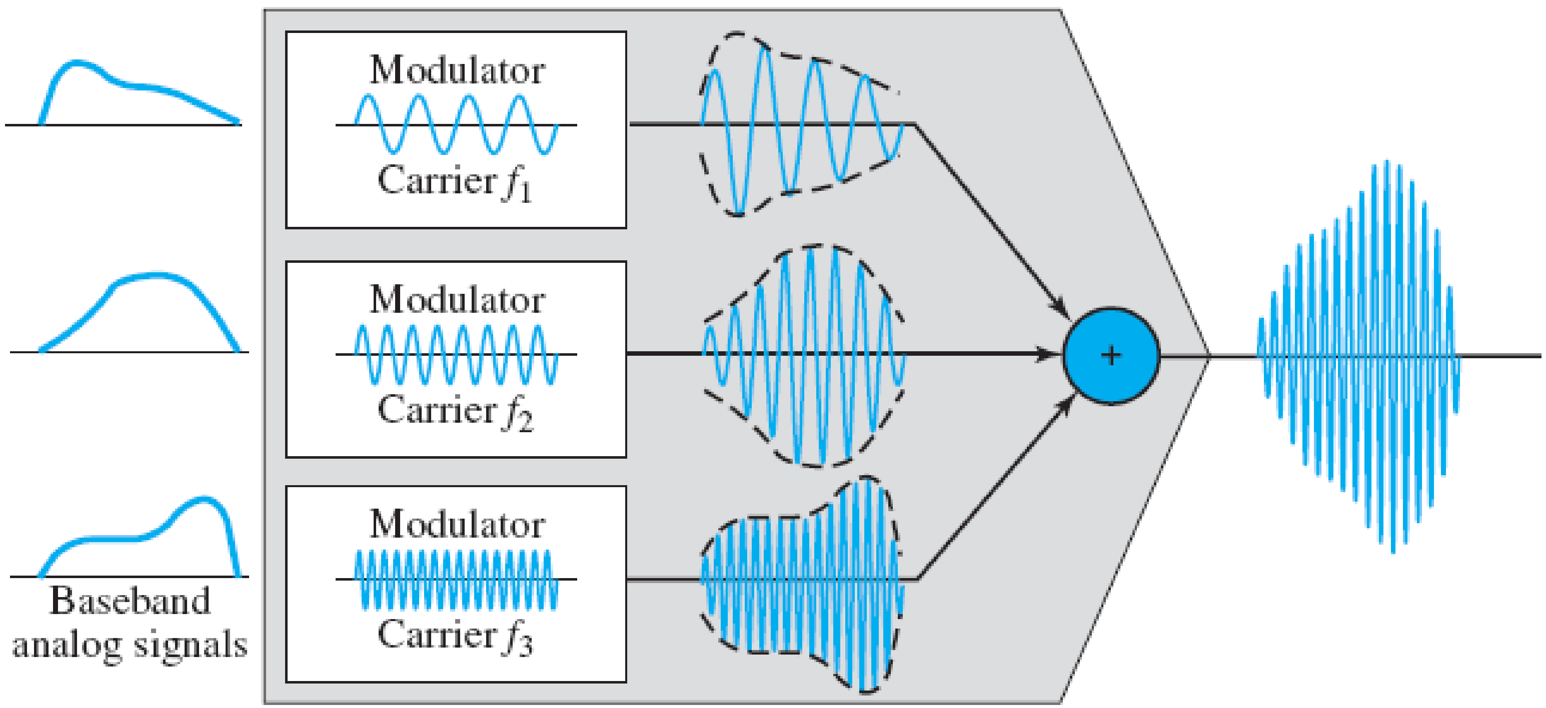


FREQUENCY-DIVISION MULTIPLEXING

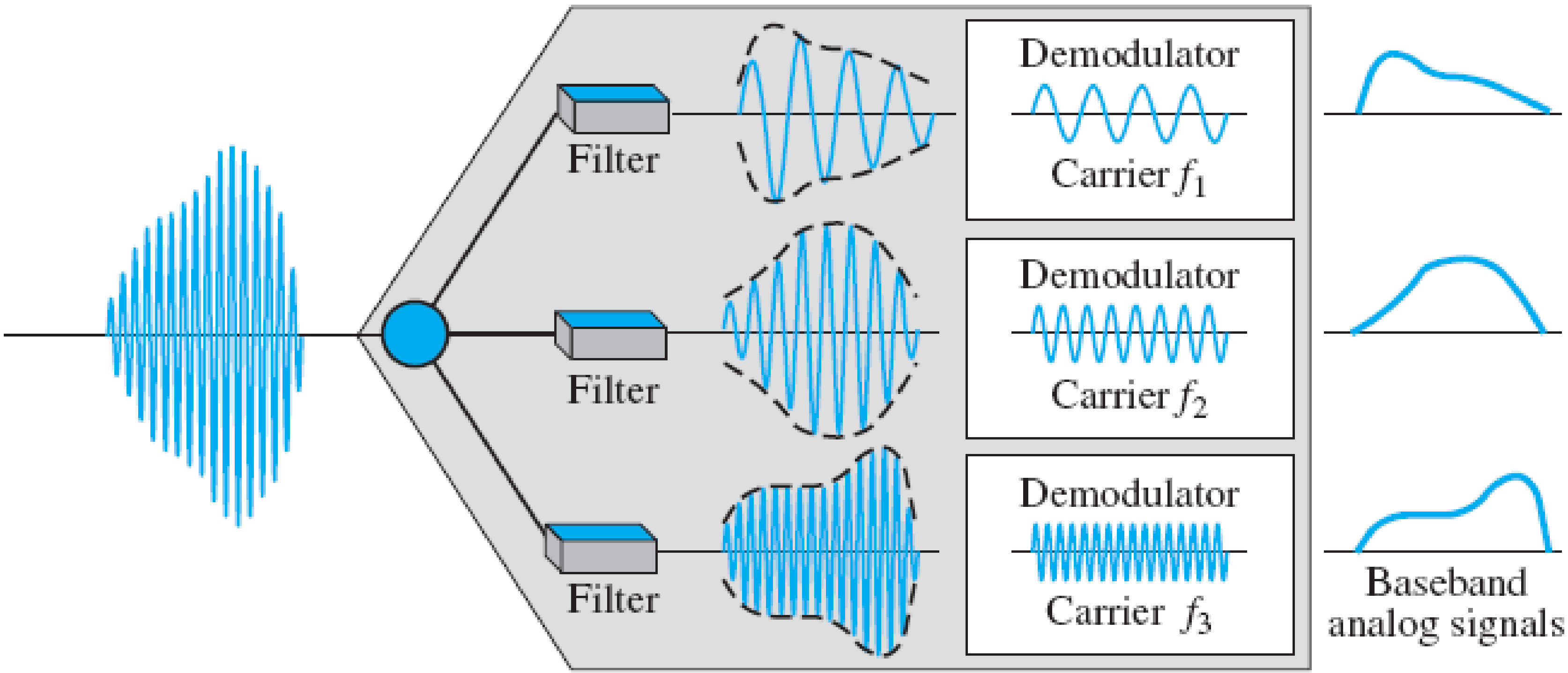
- Frequency-division multiplexing (FDM) is an analog technique that can be applied when the bandwidth of a link (in hertz) is greater than the combined bandwidths of the signals to be transmitted.



MULTIPLEXING PROCESS



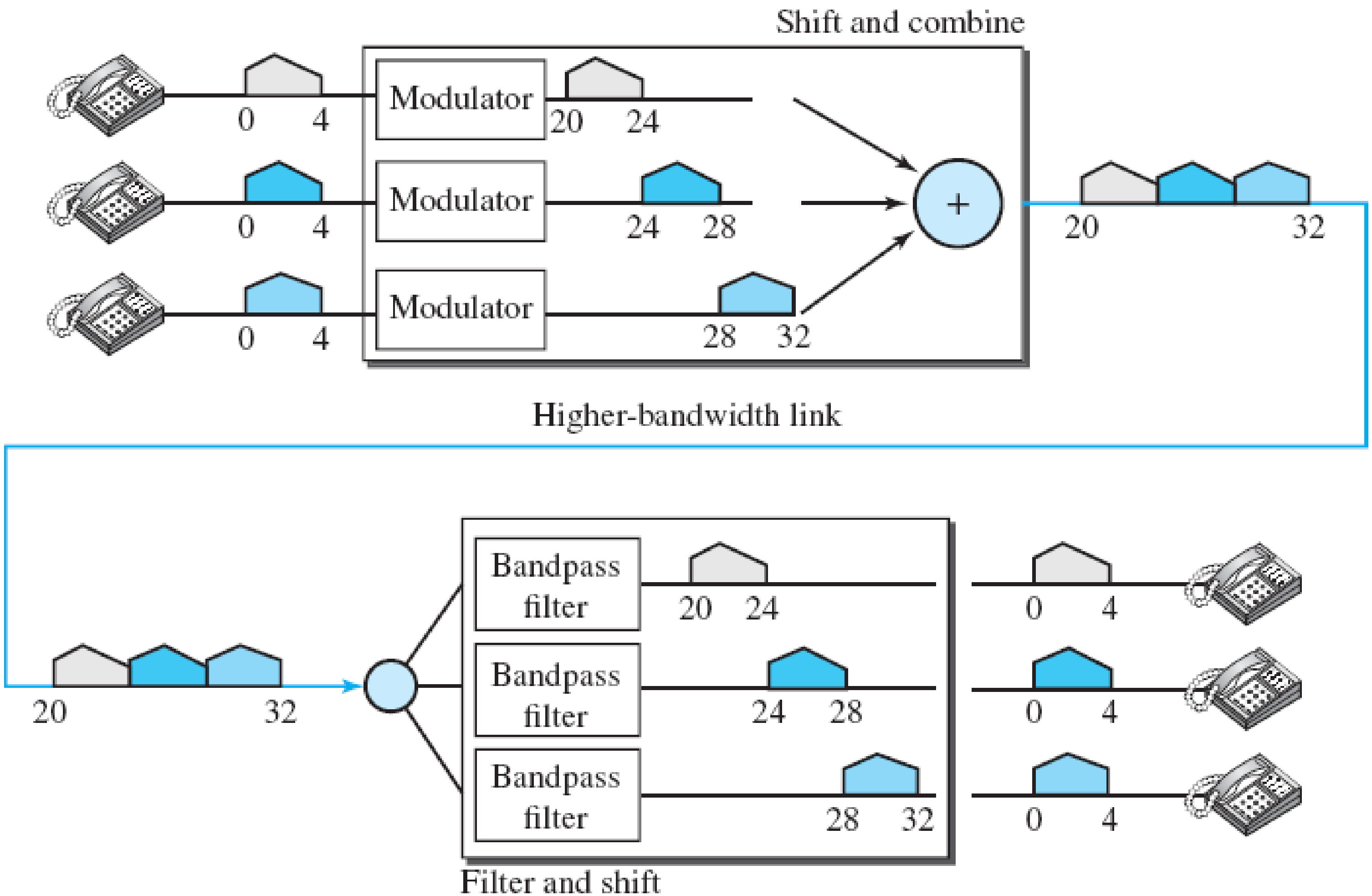
DEMULTIPLEXING PROCESS



EXAMPLE

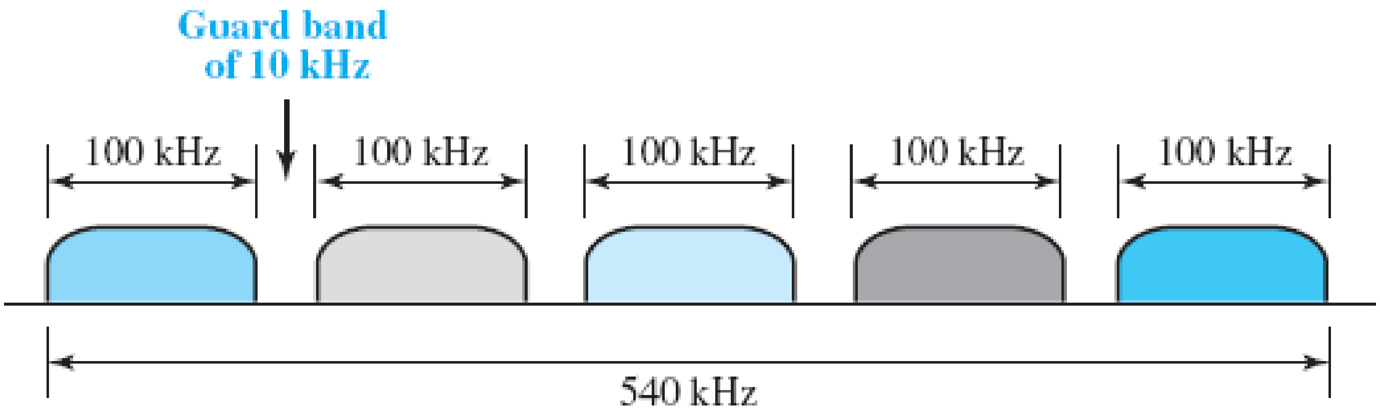
- Assume that a voice channel occupies a bandwidth of 4 kHz. We need to combine three voice channels into a link with a bandwidth of 12 kHz, from 20 to 32 kHz. Show the configuration, using the frequency domain. Assume there are no guard bands.

ANSWER

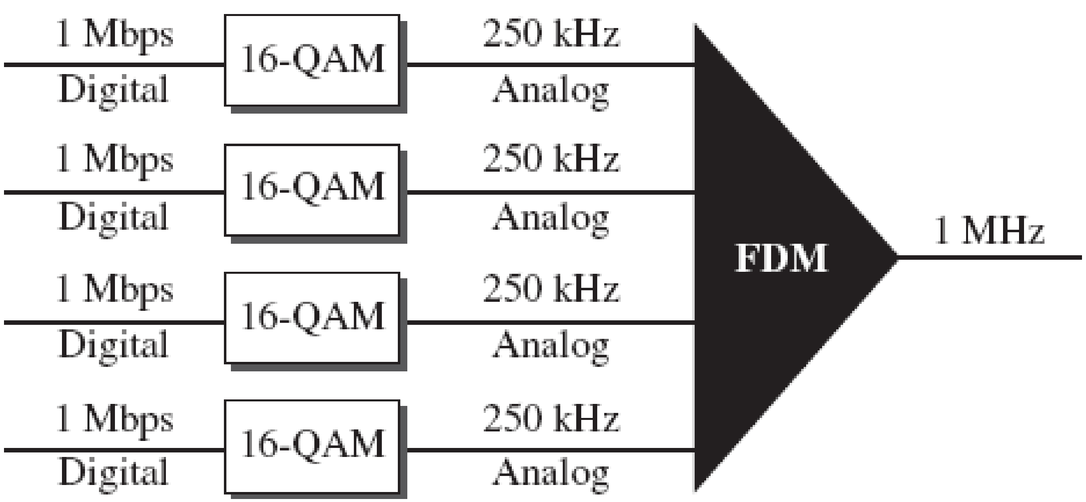


Shift and combine
Modulator
Modulator
Modulator
0 4
0 4
0 4
20 24
24 28
28 32
+
20 32
Higher-bandwidth link
20 32
Bandpass filter
Bandpass filter
Bandpass filter
20 24
24 28
28 32
0 4
0 4
0 4
Filter and shift

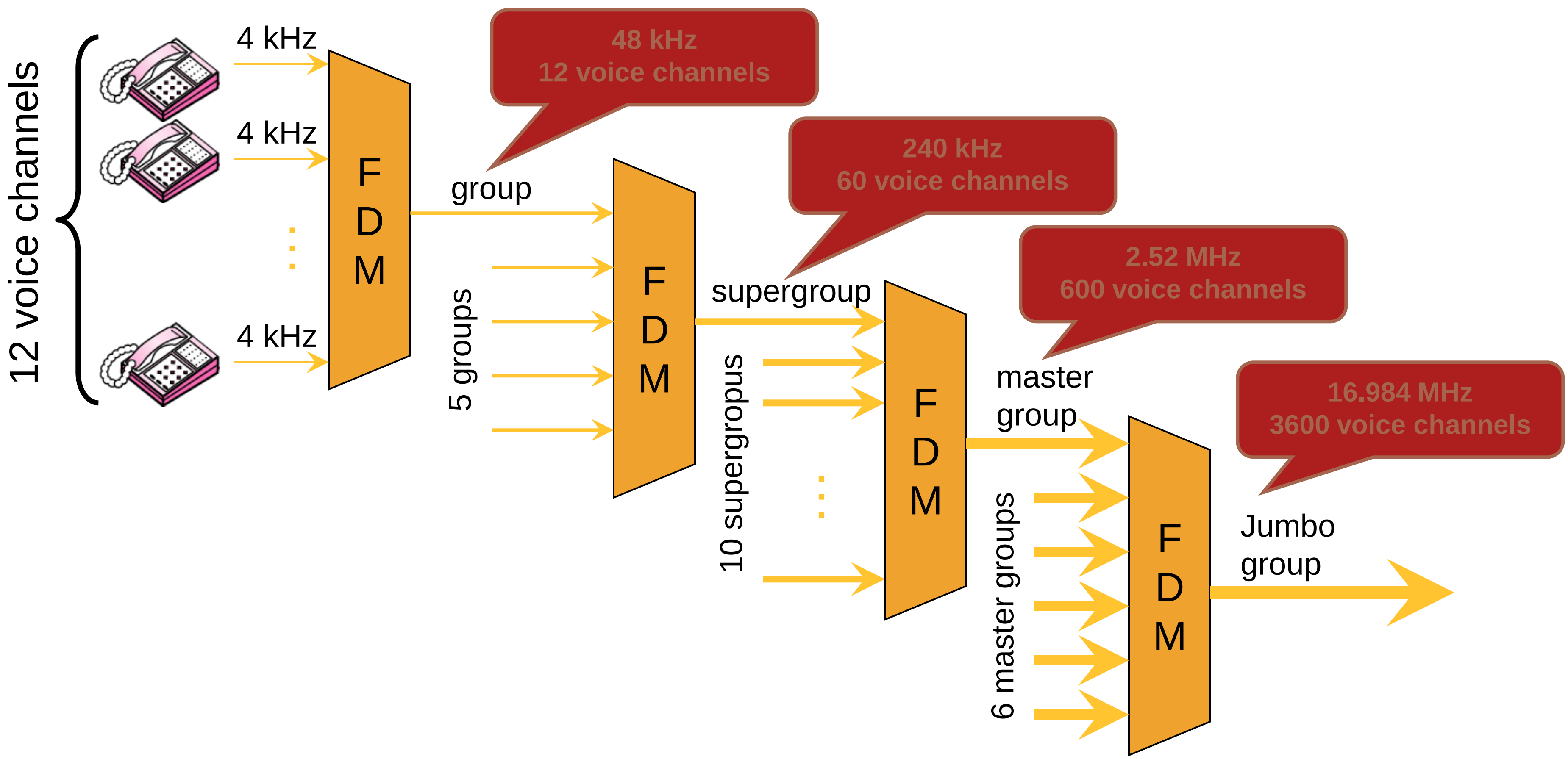
- Five channels, each with a 100-kHz bandwidth, are to be multiplexed together. What is the minimum bandwidth of the link if there is a need for a guard band of 10 kHz between the channels to prevent interference?



- The satellite channel is analog. We divide it into four channels, each channel having a 250-kHz bandwidth. Each digital channel of 1 Mbps is modulated so that each 4 bits is modulated to 1 Hz. One solution is 16-QAM modulation



ANALOG HIERARCHY



CHARUSAT

- A very common application of FDM is AM and FM radio broadcasting. Radio uses the
- air as the transmission medium. A special band from 530 to 1700 kHz is assigned
- to AM radio. All radio stations need to share this band. As discussed in Chapter 5, each
- AM station needs 10 kHz of bandwidth. Each station uses a different carrier frequency,
- which means it is shifting its signal and multiplexing. The signal that goes to the air is a
- combination of signals. A receiver receives all these signals, but filters (by tuning) only
- the one which is desired. Without multiplexing, only one AM station could broadcast
- to the common link, the air. However, we need to know that there is no physical multiplexer
- or demultiplexer here. As we will see in Chapter 12, multiplexing is done at the
- data-link layer.

- The situation is similar in FM broadcasting. However, FM has a wider band of 88
- to 108 MHz because each station needs a bandwidth of 200 kHz.
- Another common use of FDM is in television broadcasting. Each TV channel has
- its own bandwidth of 6 MHz.
- The first generation of cellular telephones (See Chapter 16) also uses FDM. Each
- user is assigned two 30-kHz channels, one for sending voice and the other for receiving.
- The voice signal, which has a bandwidth of 3 kHz (from 300 to 3300 Hz), is modulated
- by using FM. Remember that an FM signal has a bandwidth 10 times that of the
- modulating signal, which means each channel has 30 kHz (10 × 3) of bandwidth.
- Therefore, each user is given, by the base station, a 60-kHz bandwidth in a range available
- at the time of the call.

EXAPLE

- The Advanced Mobile Phone System (AMPS) uses two bands. The first band of 824 to 849 MHz
- is used for sending, and 869 to 894 MHz is used for receiving. Each user has a bandwidth of
- 30 kHz in each direction. The 3-kHz voice is modulated using FM, creating 30 kHz of modulated
- signal. How many people can use their cellular phones simultaneously?

SOLUTION

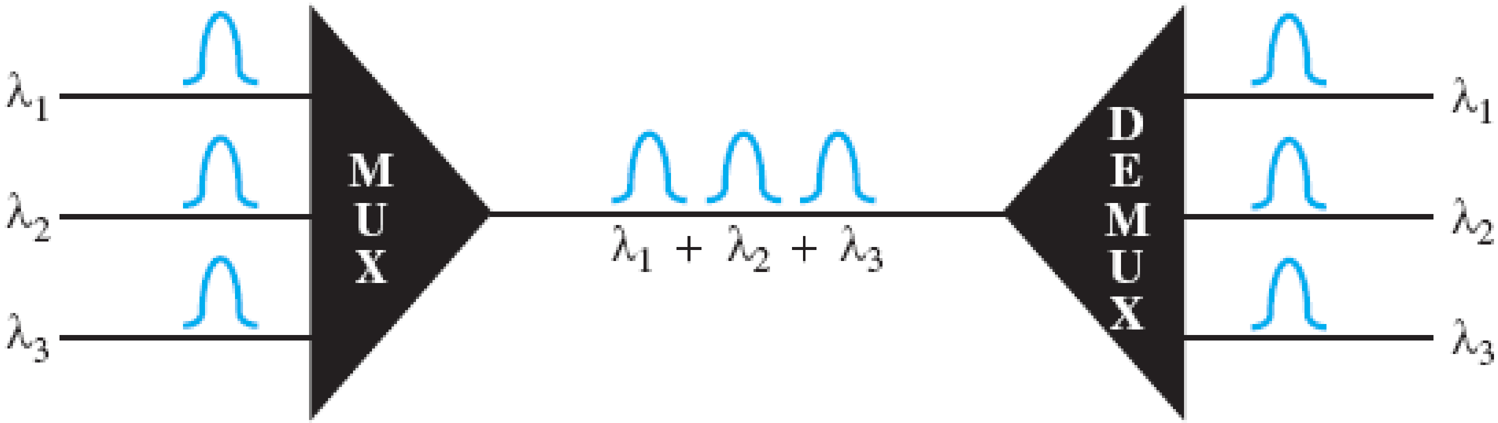
- Each band is 25 MHz. If we divide 25 MHz by 30 kHz, we get 833.33. In reality, the band
- is divided into 832 channels. Of these, 42 channels are used for control, which means only
- 790 channels are available for cellular phone users.

CONCLUSION

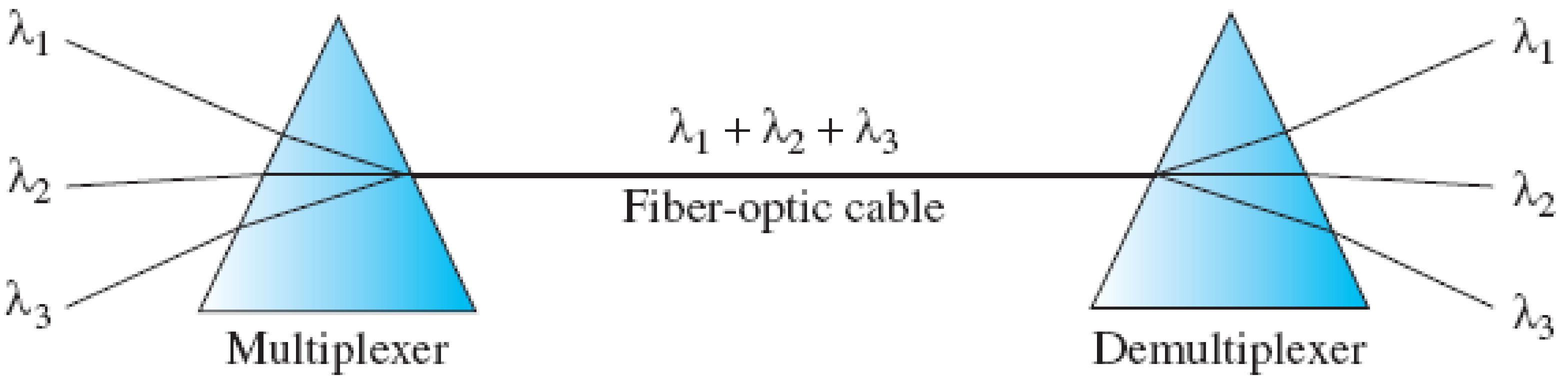
- FDM is an analog multiplexing technique that combines analog signals.
- A digital signal can be converted to an analog signal before FDM is used to multiplex them.
- In radio industry Frequecy band is allotted to one organization
- In cellular telephone system, a base station needs to assign a carrier frequency to the telephone user. There is not enough bandwidth in a cell to permanently assign a bandwidth range to every telephone user. When a user hangs up, her or his bandwidth is assigned to another caller.

WAVELENGTH-DIVISION MULTIPLEXING

- Wavelength-division multiplexing (WDM) is designed to use the high-data-rate capability of fiber-optic cable.

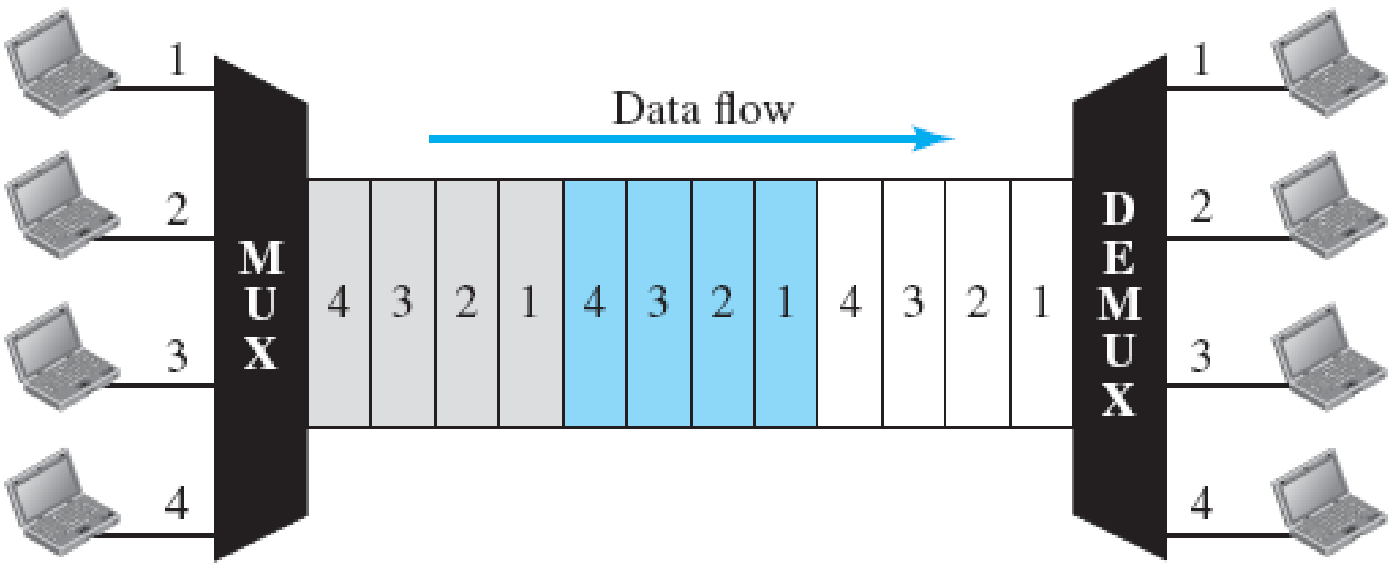


IMPLEMENTATION



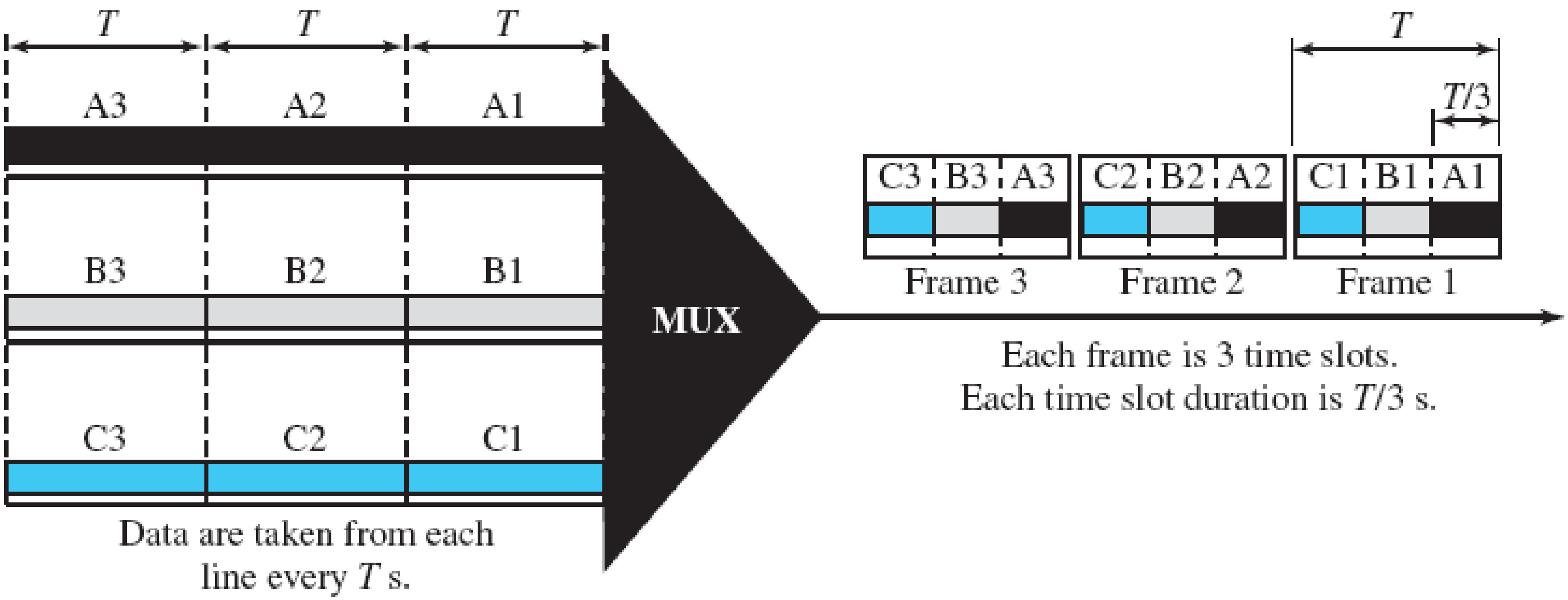
TIME-DIVISION MULTIPLEXING

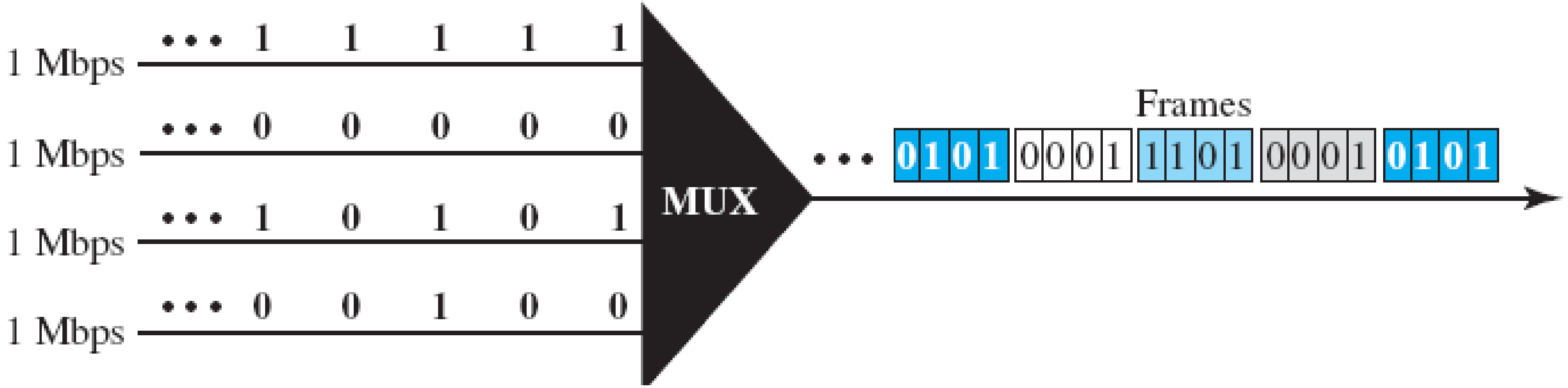
- Time-division multiplexing (TDM) is a digital process that allows several connections to share the high bandwidth of a link.



SYNCHRONOUS TDM

- In synchronous TDM, each input connection has an allotment in the output even if it is not sending data.





1 Mbps
• • • 1 1 1 1 1
1 Mbps
• • • 0 0 0 0 0
1 Mbps
• • • 1 0 1 0 1
1 Mbps
• • • 0 0 1 0 0
MUX
Frames
• • • 0 1 0 1 0 0 0 1 1 1 0 1 0 0 0 1 0 1 0 1

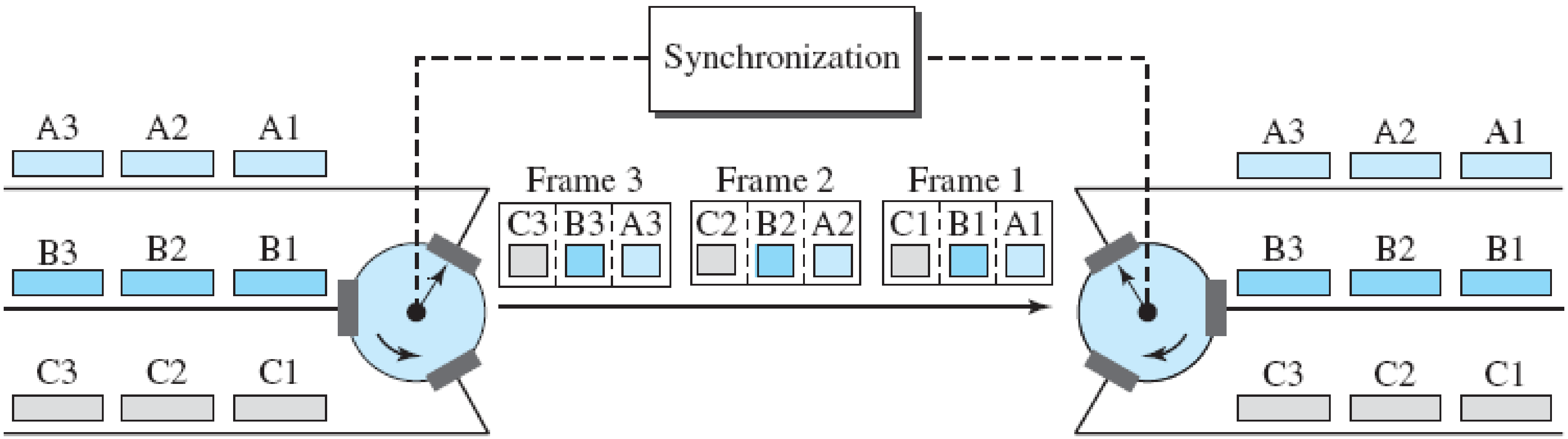
- In Figure 6.13, the data rate for each input connection is 1 kbps. If 1 bit at a time is multiplexed
- (a unit is 1 bit), what is the duration of
- 1. each input slot,
- 2. each output slot, and
- 3. each frame?
- We can answer the questions as follows:
- 1. The data rate of each input connection is 1 kbps. This means that the bit duration is 1/1000 s
- or 1 ms. The duration of the input time slot is 1 ms (same as bit duration).
- 2. The duration of each output time slot is one-third of the input time slot. This means that the
- duration of the output time slot is 1/3 ms.
- 3. Each frame carries three output time slots. So the duration of a frame is 3 · 1/3 ms, or 1 ms.
- The duration of a frame is the same as the duration of an input unit.

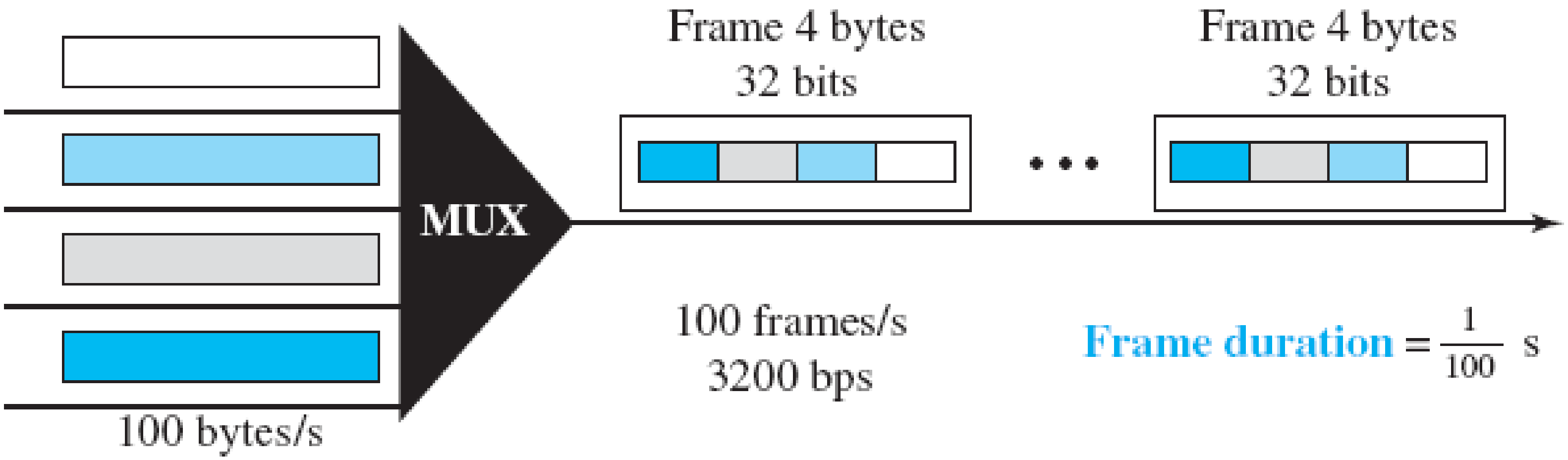
- Four 1-kbps connections are multiplexed together. A unit is 1 bit. Find (1) the duration of 1 bit before multiplexing, (2) the transmission rate of the link, (3) the duration of a time slot, and (4) the duration of a frame.

- The duration of 1 bit before multiplexing is 1/1 kbps, or 0.001 s (1 ms).
- The rate of the link is 4 times the rate of a connection, or 4 kbps.
- The duration of each time slot is one-fourth of the duration of each bit before multiplexing, or 1/4 ms or 250 micros. Note that we can also calculate this from the data rate of the link, 4 kbps. The bit duration is the inverse of the data rate, or 1/4 kbps or 250 μs.
- The duration of a frame is always the same as the duration of a unit before multiplexing, or 1 ms. We can also calculate this in another way. Each frame in this case has four time slots. So the duration of a frame is 4 times 250 micros, or 1 ms.

IMPLEMENTATION

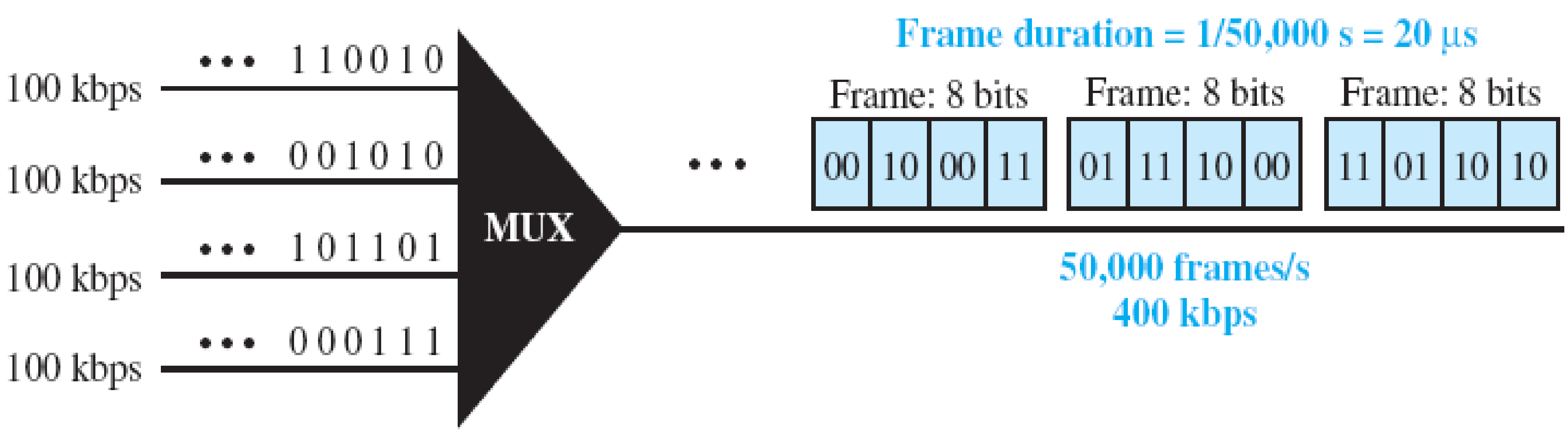
- Interleaving




Frame 4 bytes
32 bits
Frame 4 bytes
32 bits
MUX
100 frames/s
3200 bps
Frame duration = $\frac{1}{100}$ s
100 bytes/s

EXAMPLE

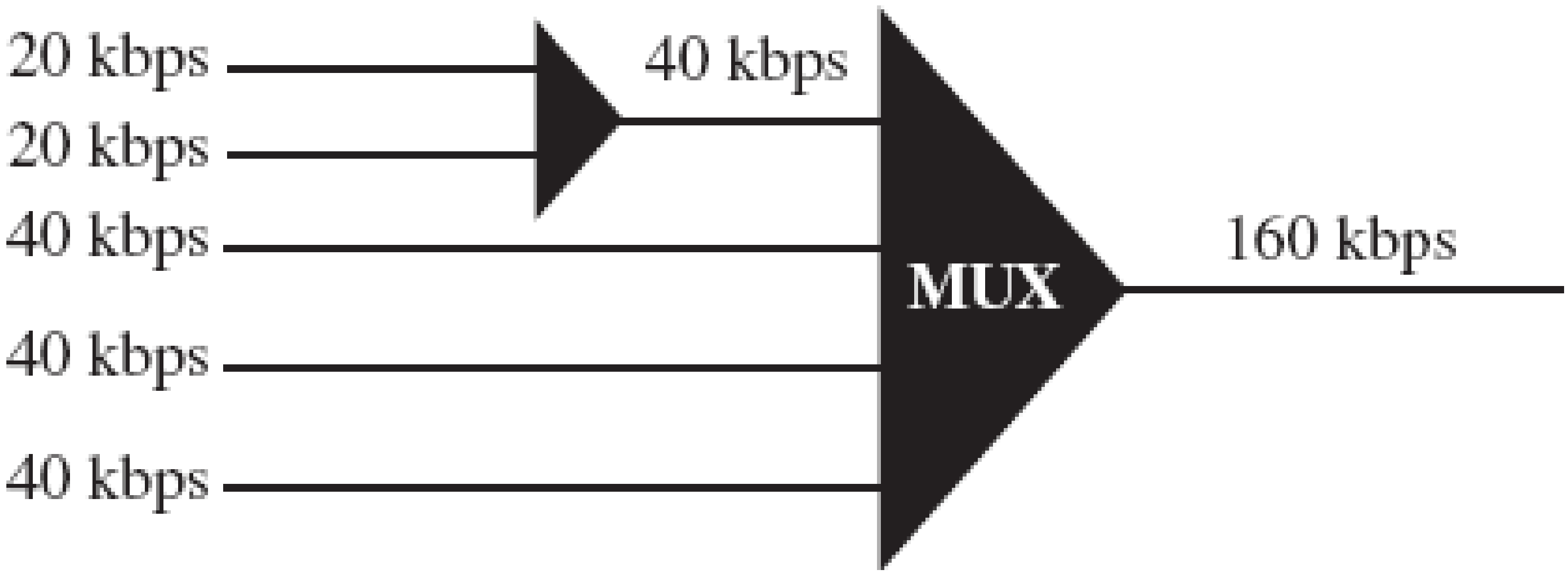
- A multiplexer combines four 100-kbps channels using a time slot of 2 bits. Show the output with four arbitrary inputs. What is the frame rate? What is the frame duration? What is the bit rate? What is the bit duration?



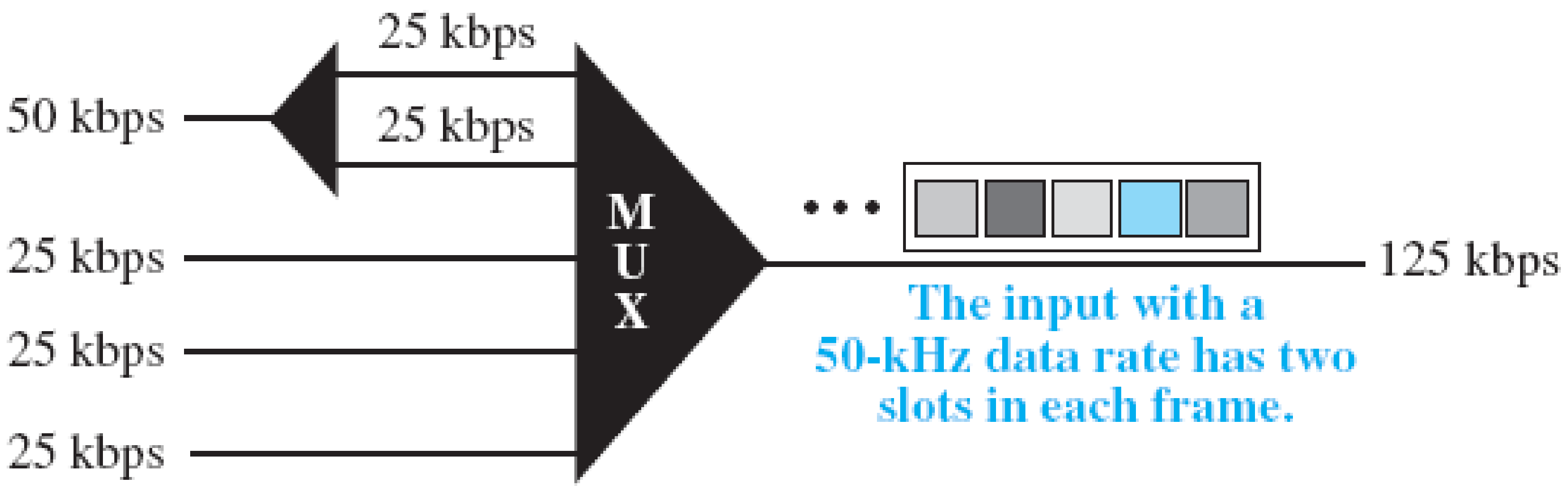
PROBLEM1: DATA RATE MANAGEMENT

- Three methods
  - multilevel multiplexing,
  - multiple-slot allocation, and
  - pulse stuffing.

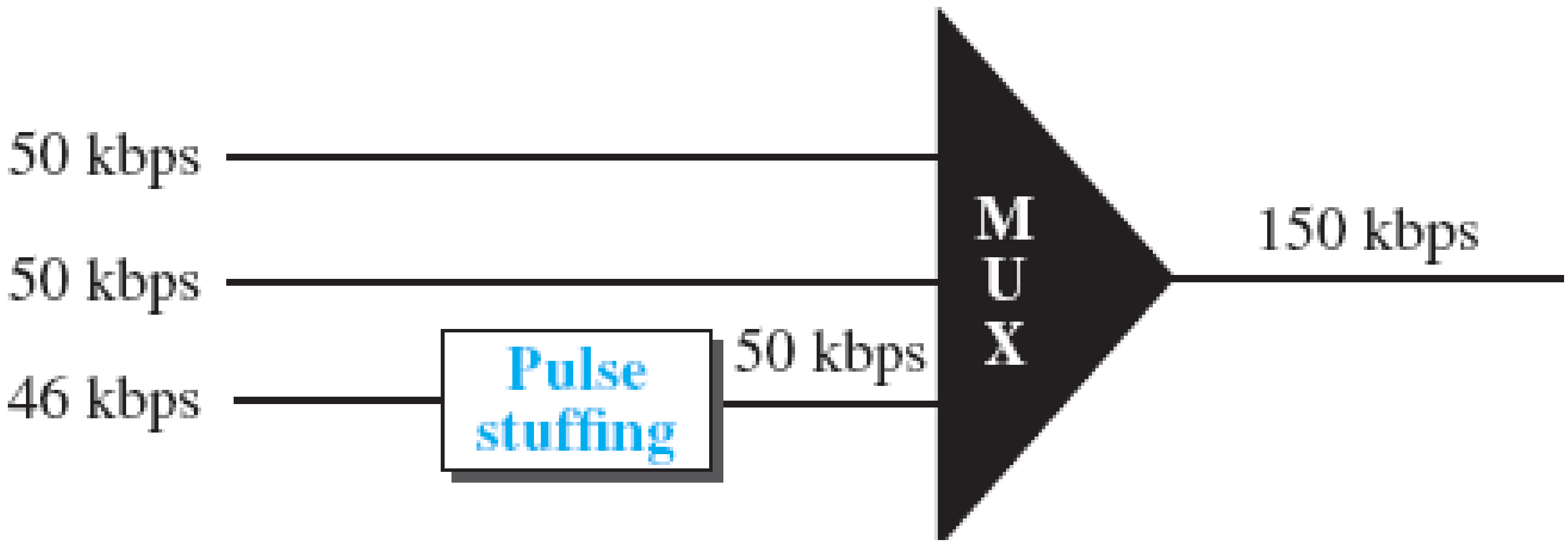
MULTILEVEL MULTIPLEXING



MULTIPLE-SLOT ALLOCATION

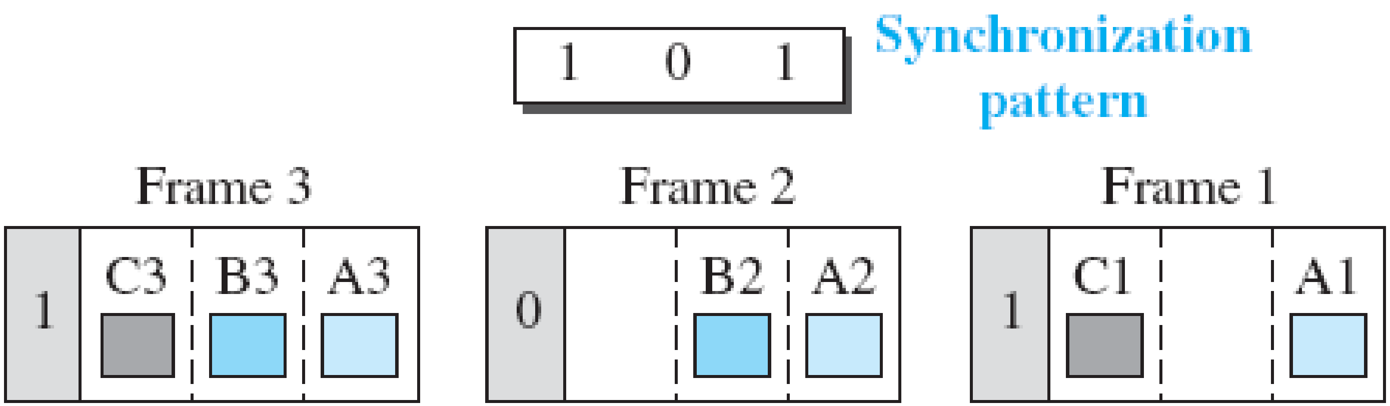


PULSE STUFFING



PROBLEM2

- Synchronization between the multiplexer and demultiplexer is a major issue.
- Solution: Framing Bit



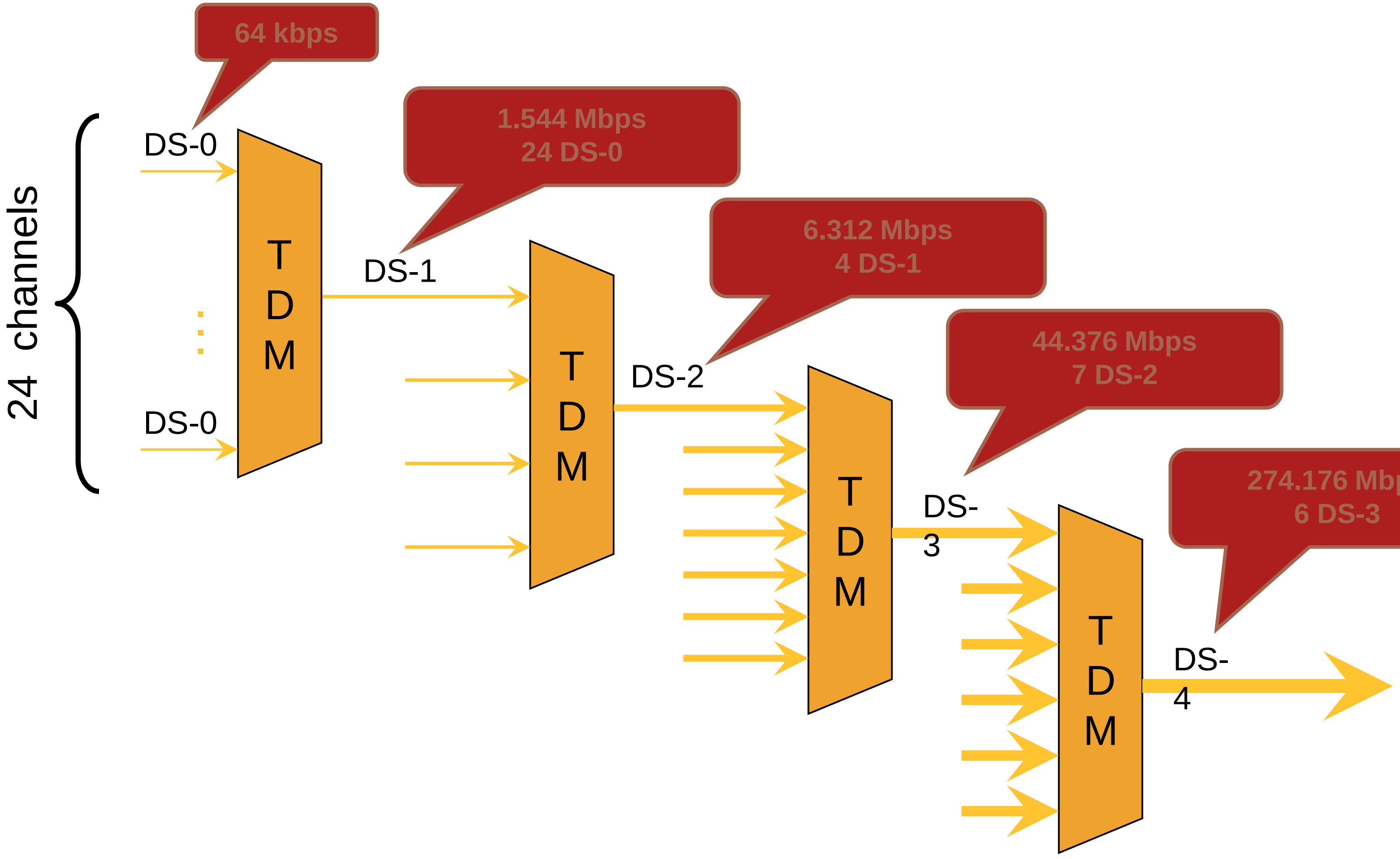
EXERCISE

- We have four sources, each creating 250 characters per second. If the interleaved unit is a character and 1 synchronizing bit is added to each frame, find (1) the data rate of each source, (2) the duration of each character in each source, (3) the frame rate, (4) the duration of each frame, (5) the number of bits in each frame, and (6) the data rate of the link.

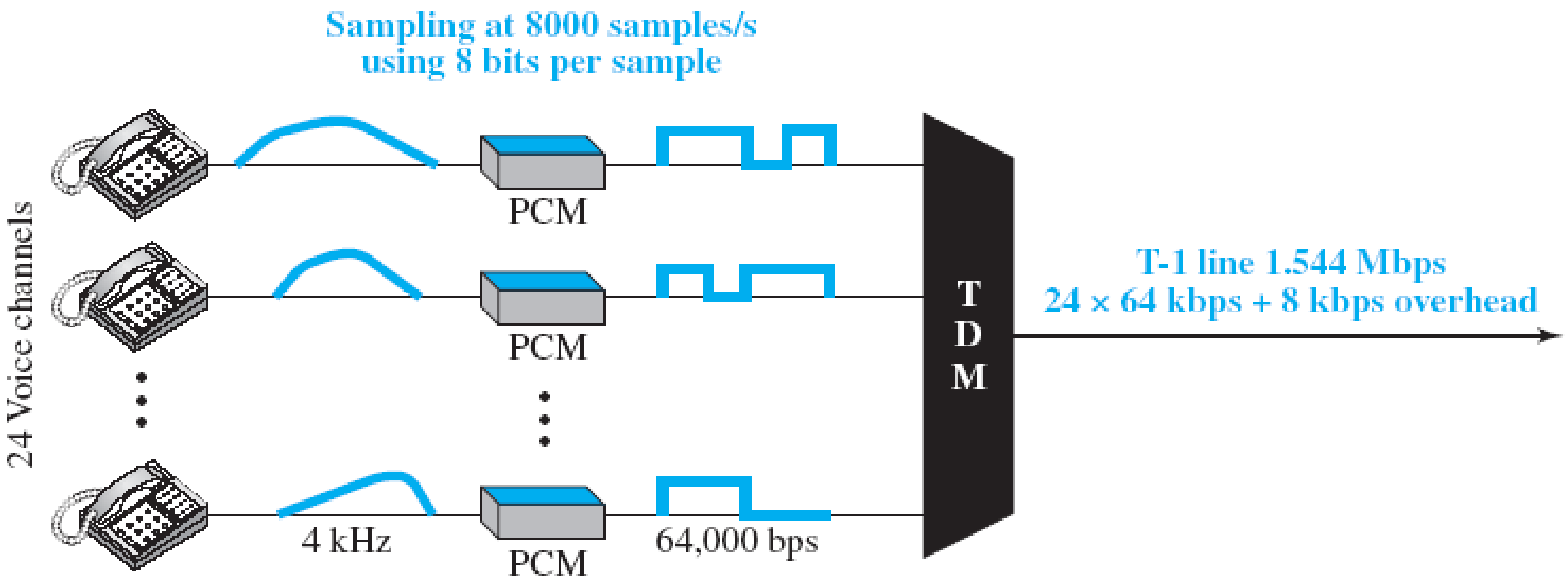
SOLUTION

- The data rate of each source is 250 × 8 = 2000 bps = 2 kbps.
- 2. Each source sends 250 characters per second; therefore, the duration of a character is 1/250 s,
- or 4 ms.
- 3. Each frame has one character from each source, which means the link needs to send
- 250 frames per second to keep the transmission rate of each source.
- 4. The duration of each frame is 1/250 s, or 4 ms. Note that the duration of each frame is the
- same as the duration of each character coming from each source.
- 5. Each frame carries 4 characters and 1 extra synchronizing bit. This means that each frame is
- 4 × 8 + 1 = 33 bits.
- 6. The link sends 250 frames per second, and each frame contains 33 bits. This means that the
- data rate of the link is 250 × 33, or 8250 bps. Note that the bit rate of the link is greater than
- the combined bit rates of the four channels. If we add the bit rates of four channels, we get
- 8000 bps. Because 250 frames are traveling per second and each contains 1 extra bit for
- synchronizing, we need to add 250 to the sum to get 8250 bps.

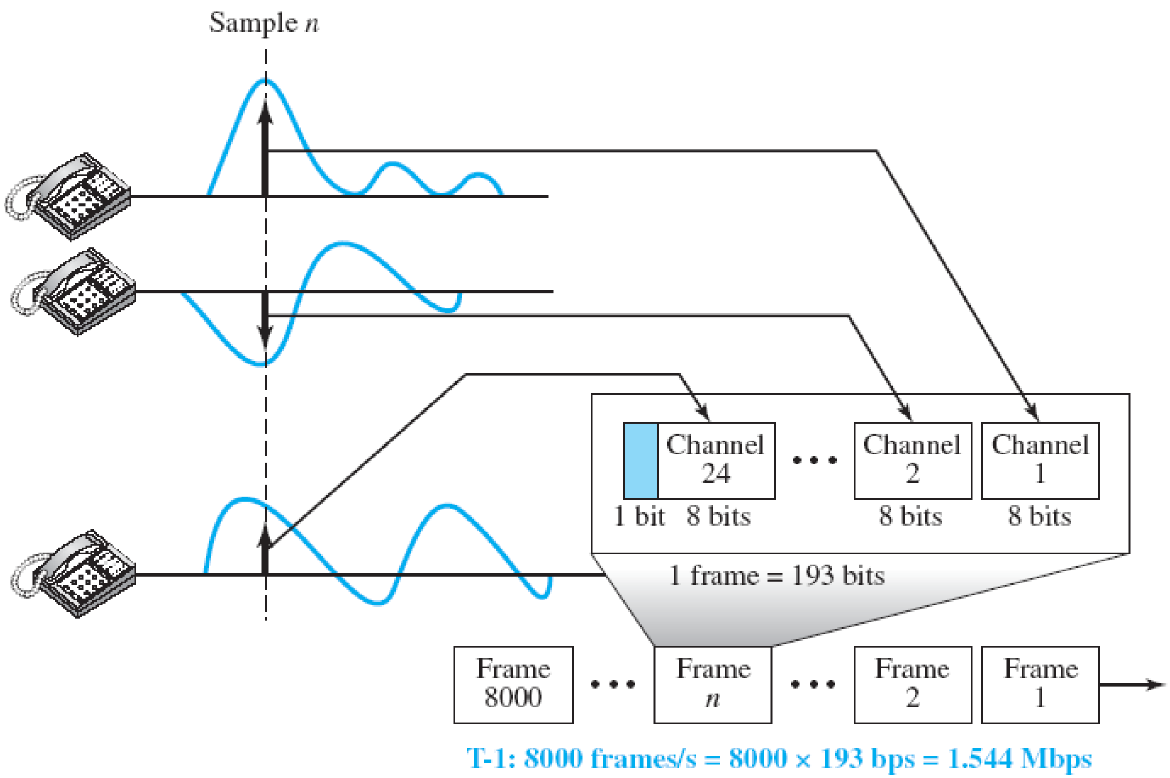
DIGITAL SIGNAL SERVICE



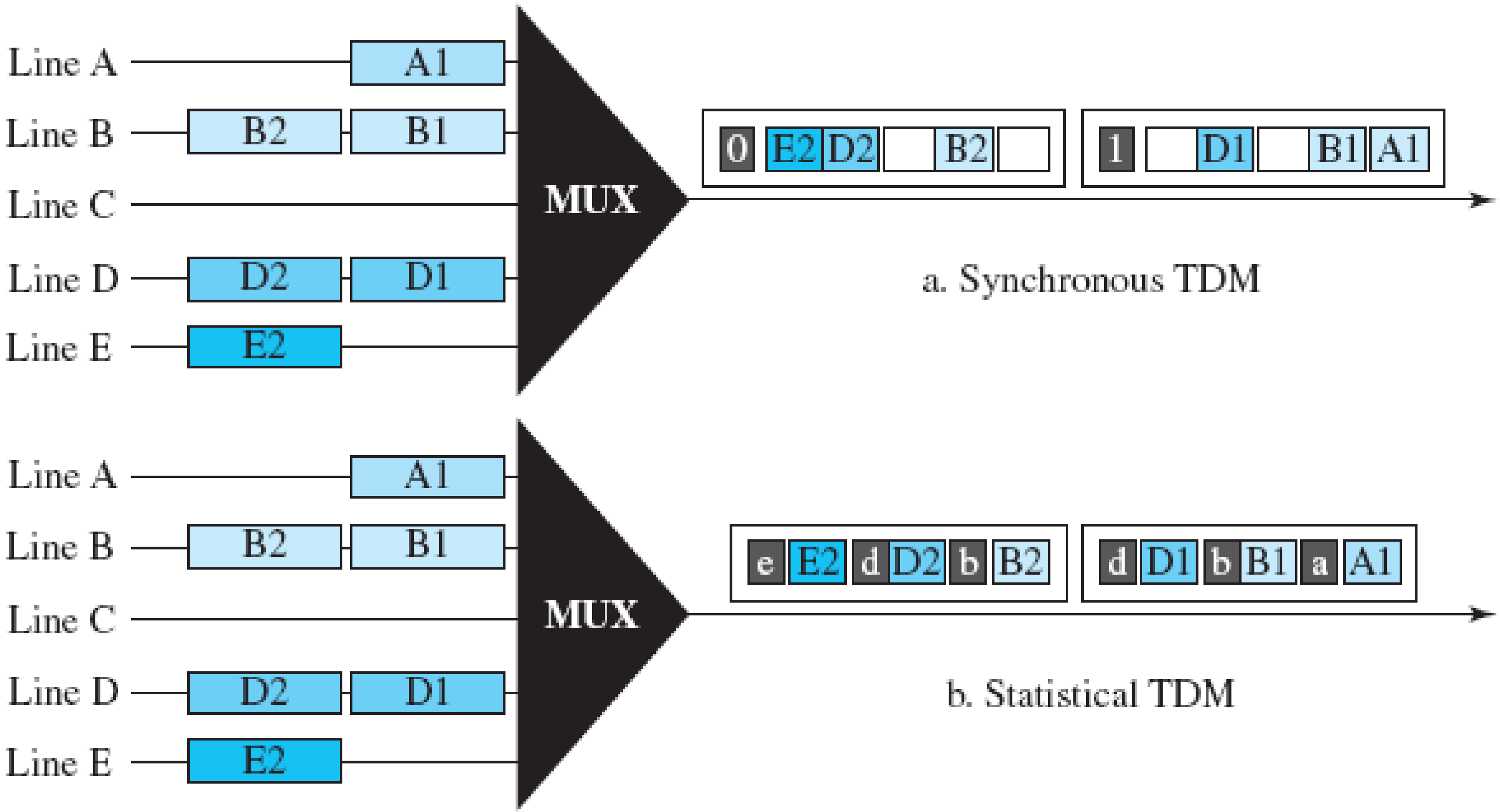
T LINES FOR ANALOG TRANSMISSION



- The frame used on a T-1 line is usually 193 bits divided into 24 slots of 8 bits each plus 1 extra bit for synchronization (24 × 8 + 1 = 193);



STATISTICAL TIME-DIVISION MULTIPLEXING



CONCLUSION

- WDM is an analog multiplexing technique to combine optical signals.
- We also need to remember that TDM is, in principle, a digital multiplexing technique.
- We are concerned with only multiplexing, not switching. This means that all the data in a message from source 1 always go to one specific destination, be it 1, 2, 3, or 4. The delivery is fixed and unvarying, unlike switching.

- In synchronous TDM, the data rate of the link is n times faster, and the unit duration is n times shorter.

SPREAD SPECTRUM

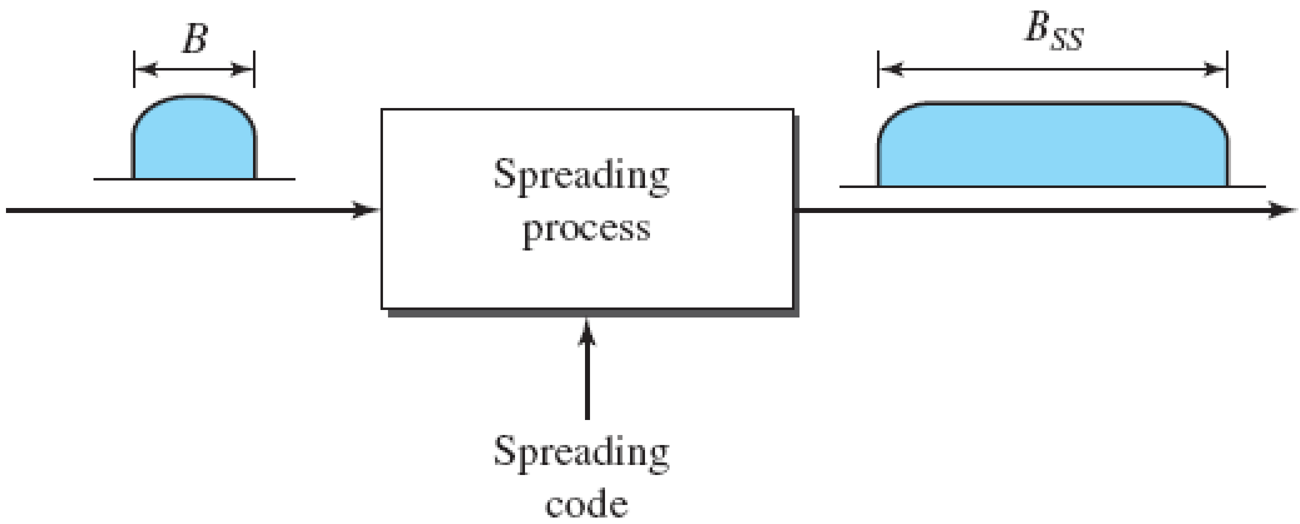
- Spread spectrum is designed to be used in wireless applications (LANs and WANs). In these types of applications, we have some concerns that outweigh bandwidth efficiency. In wireless applications, all stations use air (or a vacuum) as the medium for communication. Stations must be able to share this medium without interception by an eavesdropper and without being subject to jamming from a malicious intruder

- The expanded bandwidth allows the source to wrap its message in a protective envelope for a more secure transmission.
- An analogy is the sending of a delicate, expensive gift. We can insert the gift in a special box to prevent it from being damaged during transportation, and we can use a superior delivery service to guarantee the safety of the package.

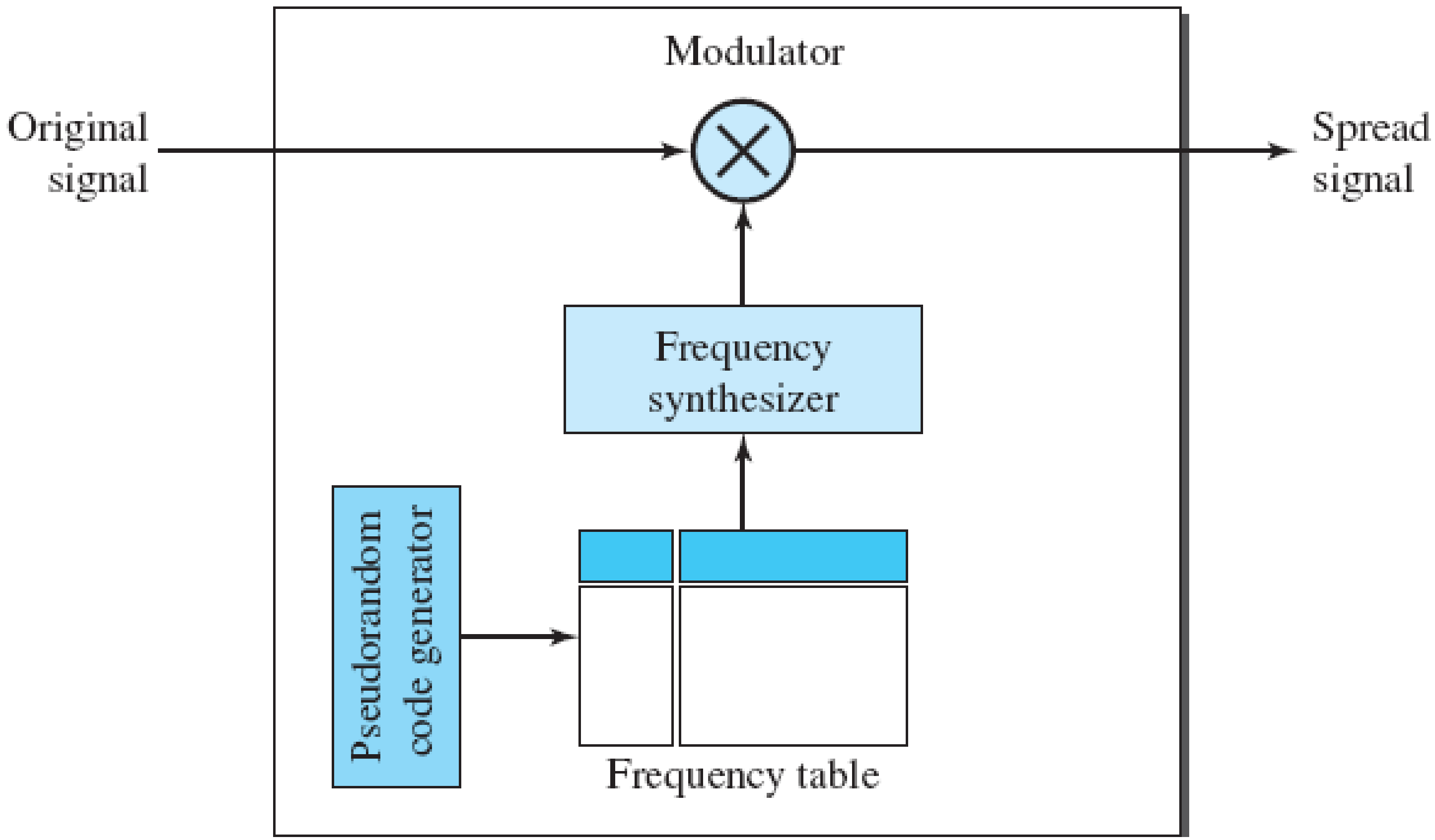
TWO PRINCIPLES:

- The bandwidth allocated to each station needs to be, by far, larger than what is needed. This allows redundancy.
- The expanding of the original bandwidth B to the bandwidth Bss must be done by a process that is independent of the original signal. In other words, the spreading process occurs after the signal is created by the source.

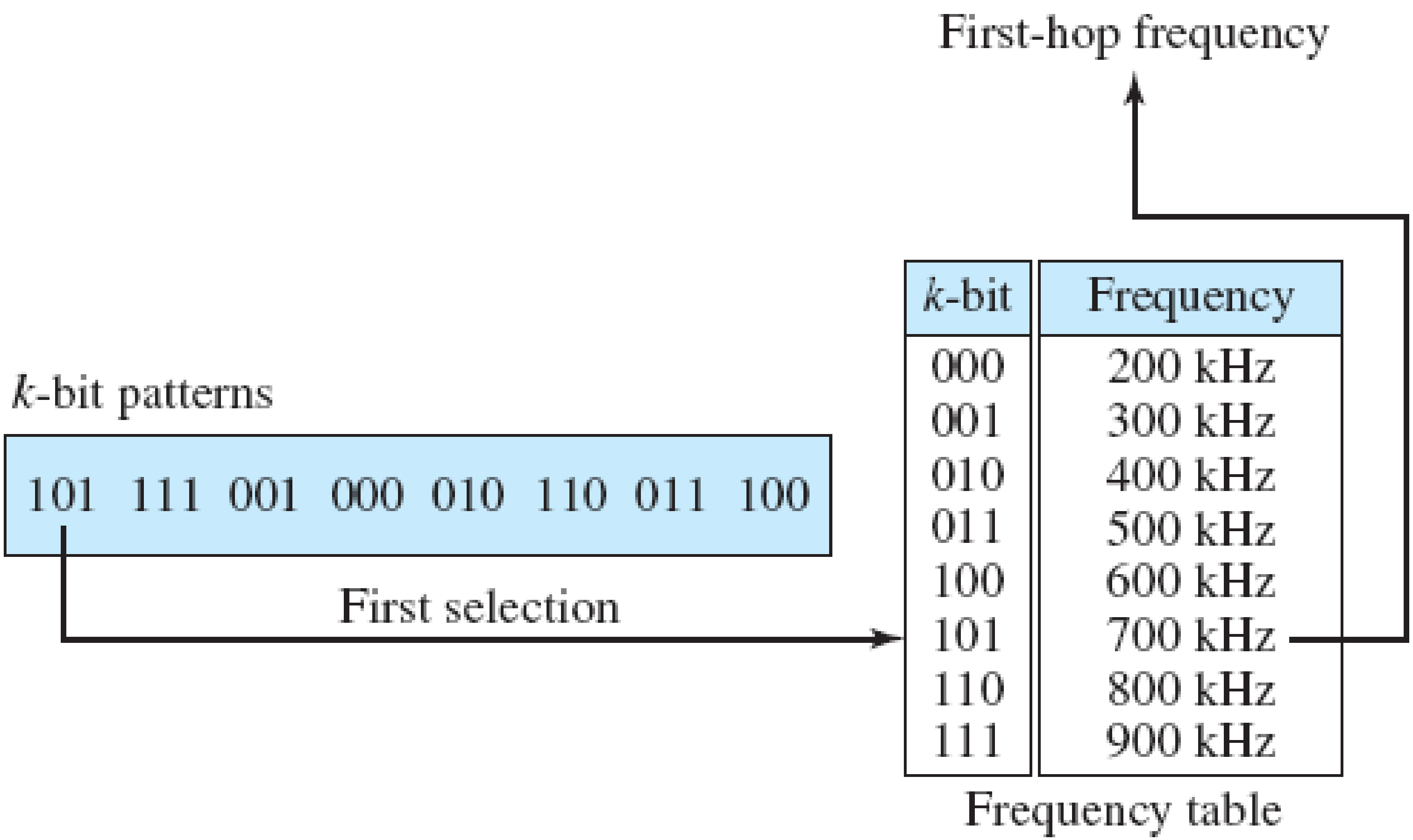
IMPLEMENTATION



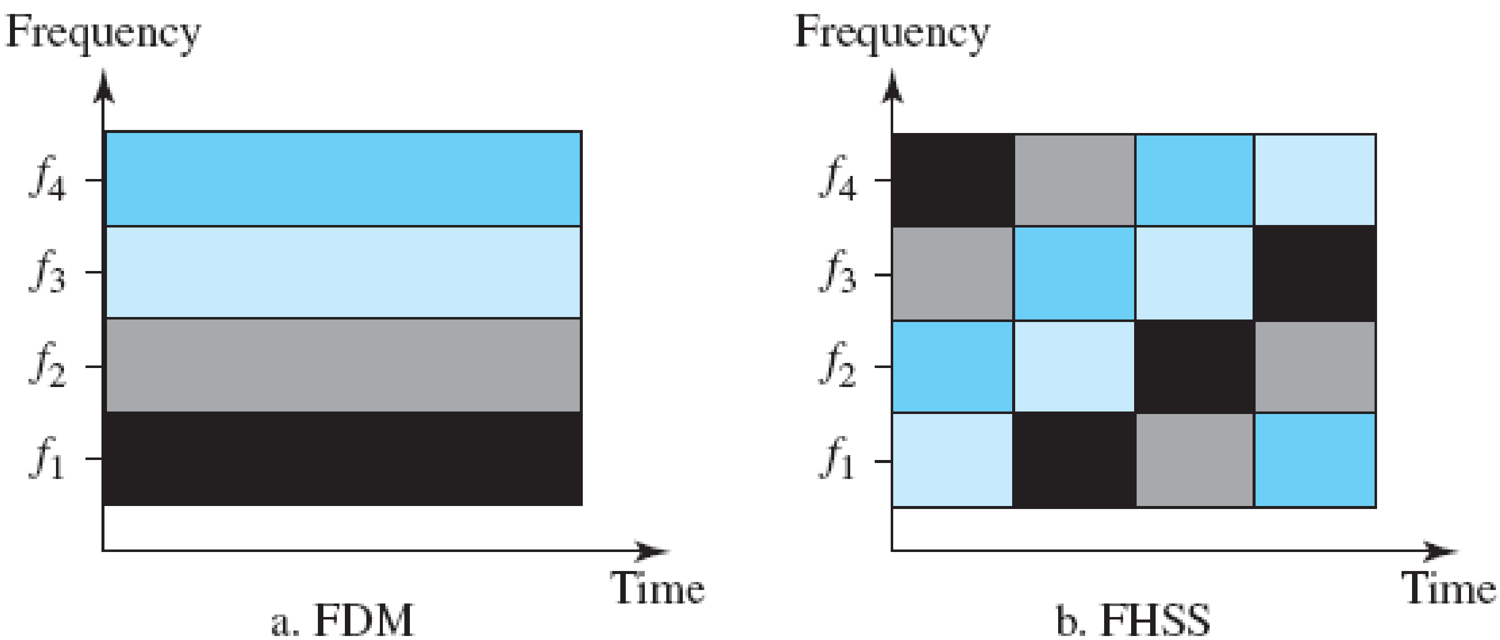
FREQUENCY HOPPING SPREAD SPECTRUM



FREQUENCY HOPPING SPREAD SPECTRUM



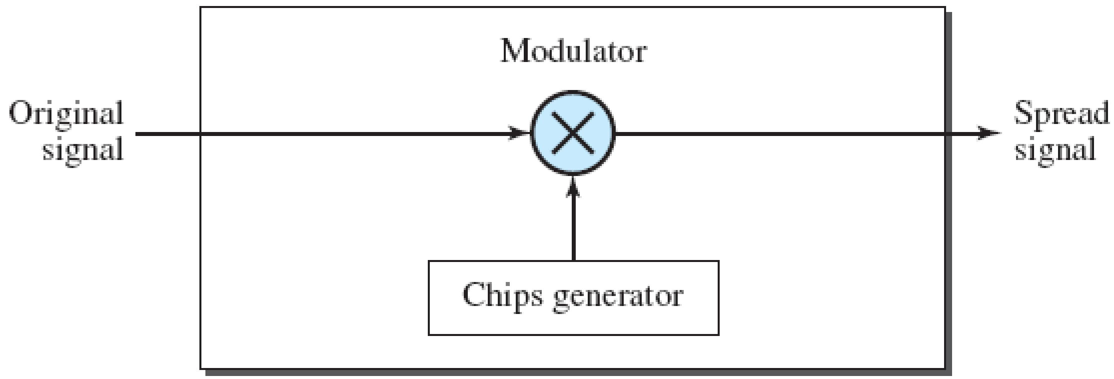
COMPARISION

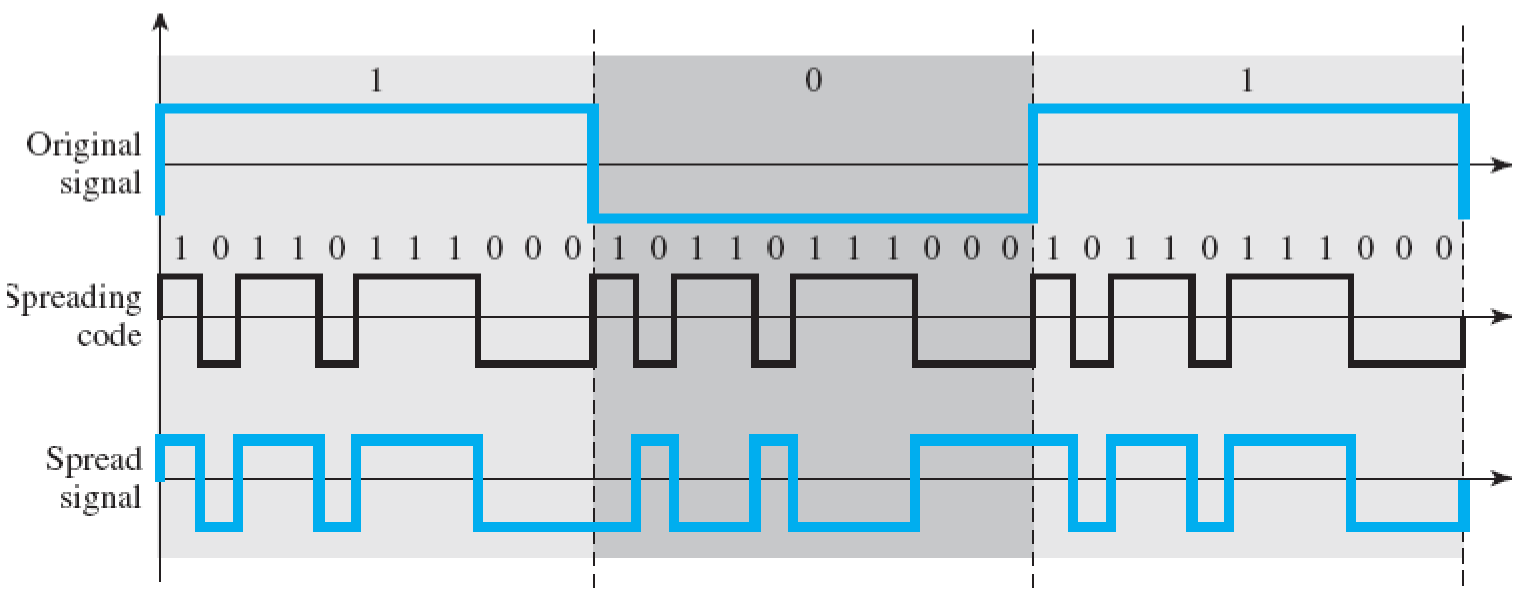


DIRECT SEQUENCE SPREAD SPECTRUM

- The direct sequence spread spectrum (DSSS) technique also expands the bandwidth of the original signal, but the process is different. In DSSS, we replace each data bit with n bits using a spreading code. In other words, each bit is assigned a code of n bits, called chips, where the chip rate is n times that of the data bit.

IMPLEMENTATION





- Thank you